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Post-Shot Radiation Environment in the National Ignition Facility

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Disclaimer

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Presentation to

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Outline

I. The NIF facility modeling

II. Development of planning tools for estimating radiation exposure

III. Results of activation analysis

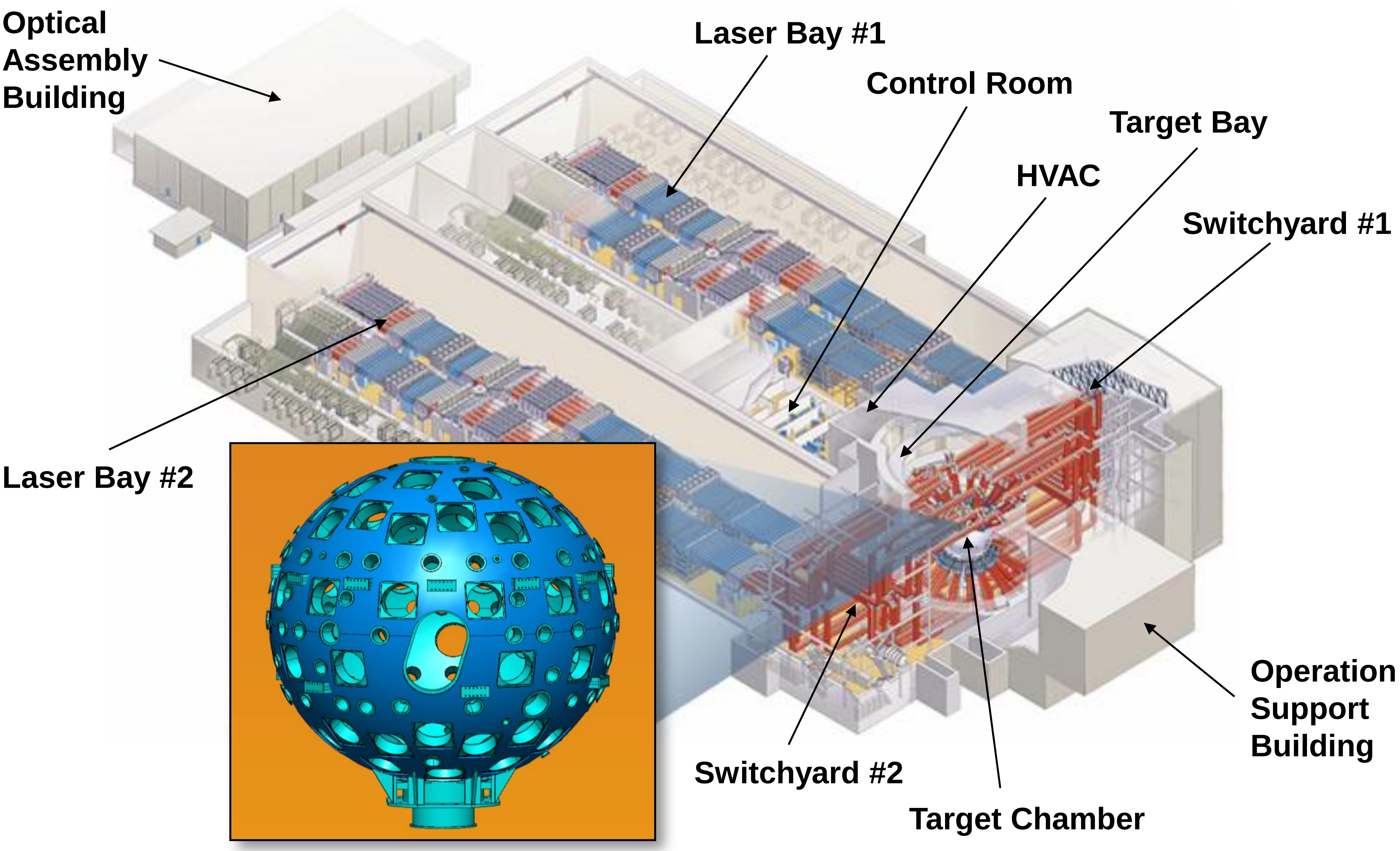
IV. Gamma spectrometry

V. Worker dose management

Introduction

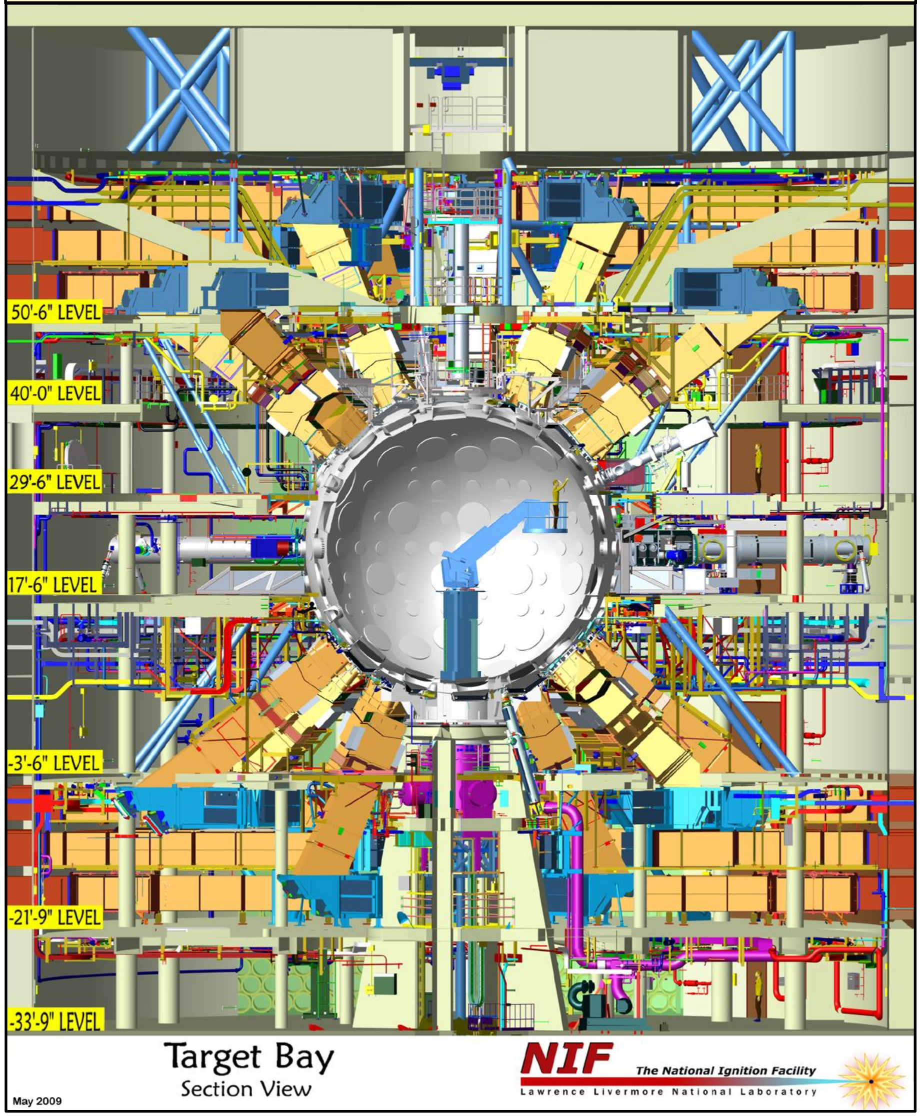
- A detailed 3-D model of NIF Target Bay (TB) has been developed
- An automated mechanism has been developed to allow for simultaneous analysis of contribution from all activated structures inside the TB
  - AAMI (*Automated ALARA-MCNP Interface*) is a coupling scheme between radiation transport and neutron activation codes
  - NEET (*NIF Exposure Estimation Tool*) is a web application that combines the information computed by AAMI with a given shot schedule to compute and display dose rate maps as a function of time
- Work planners can use NEET to estimate individual worker dose based on time required for a specific activity and for a specific location
- Estimated dose rate values are verified through the use of gamma spectrometry and passive dosimeters

NIF layout

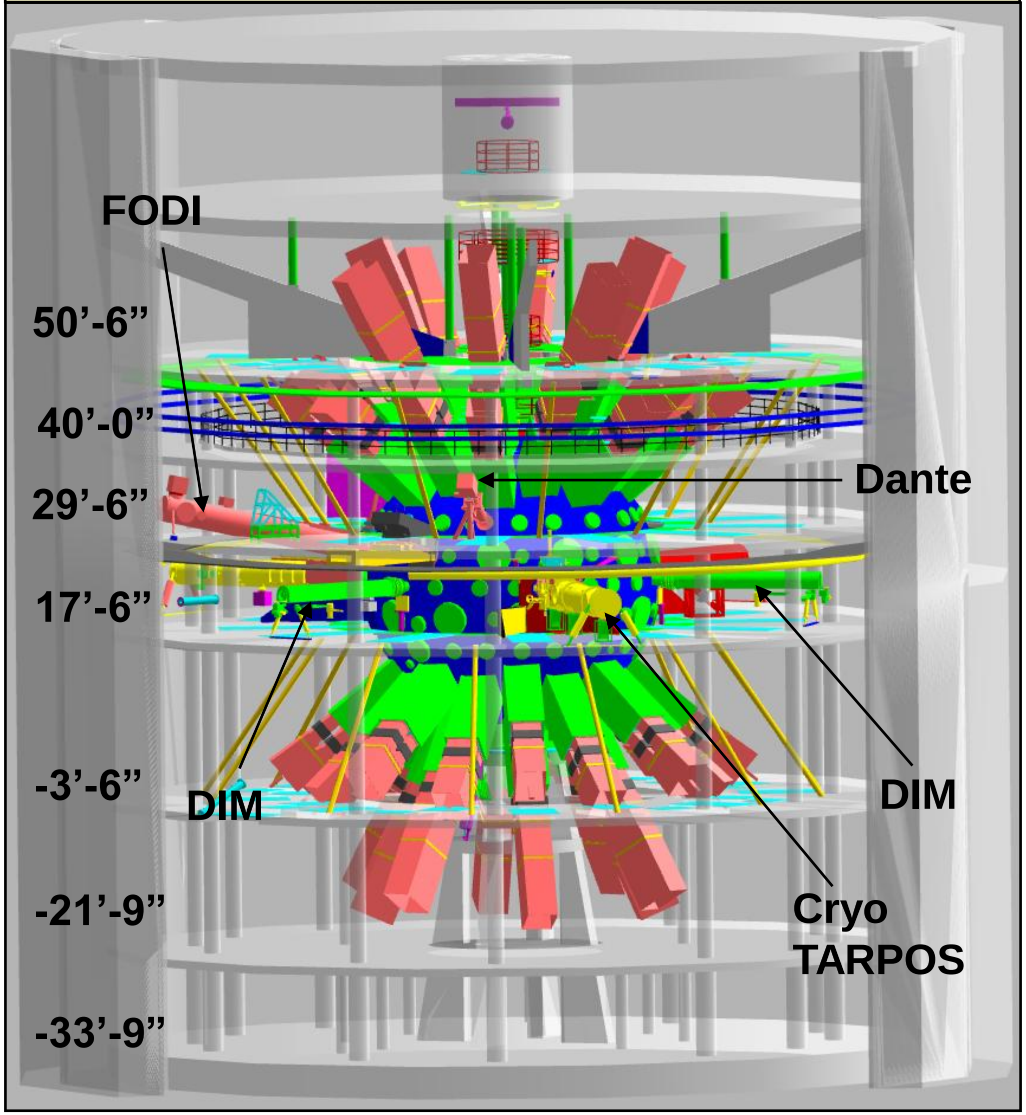

Optical Assembly Building
Laser Bay #1
Control Room
Target Bay
HVAC
Switchyard #1
Laser Bay #2
Operation Support Building
Switchyard #2
Target Chamber

NIF Target Bay Model

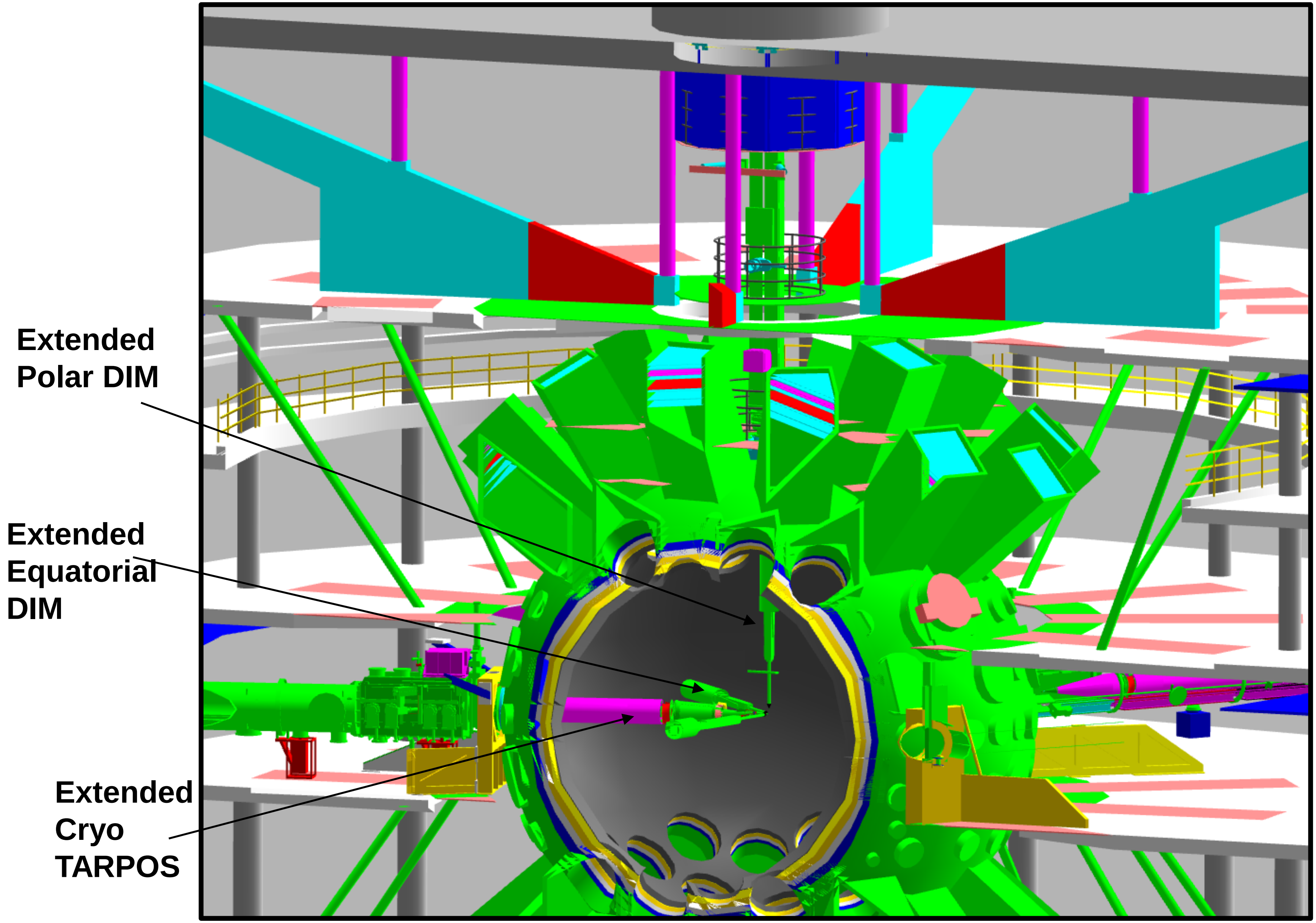
Sectional View of the Target Bay



MCNP Target Bay Model



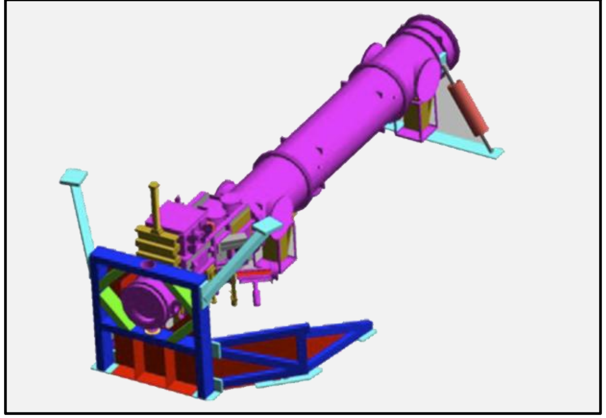
TB model: close-up sectional view



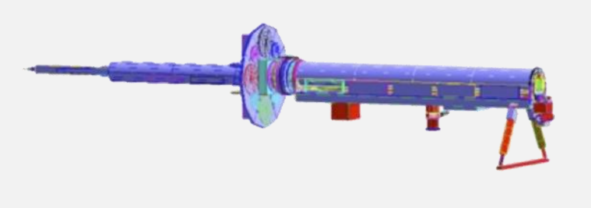
Features of the MCNP Target Bay model

- **Structures including the floors, walls, support columns, braces, guard railing, and maintenance platforms**
- **Target Chamber with 120 diagnostic ports and 24 direct-drive ports**
- **Forty eight Final Optics Assemblies (FOAs)**
- **Target positioners (Cryo TARPOS and TARPOS) in the extended and retracted positions**
- **Target Alignment System (TASPOS)**
- **Three Diagnostic Instrument Manipulators (DIMs) in the extended and retracted positions**
- **X-ray diagnostics instruments: Dante and FFLEX**
- **Magnetic Recoil Spectrometer (MRS)**

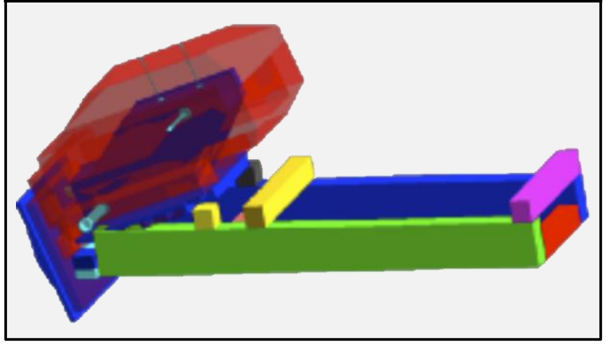
CryoTARPOS



DIM

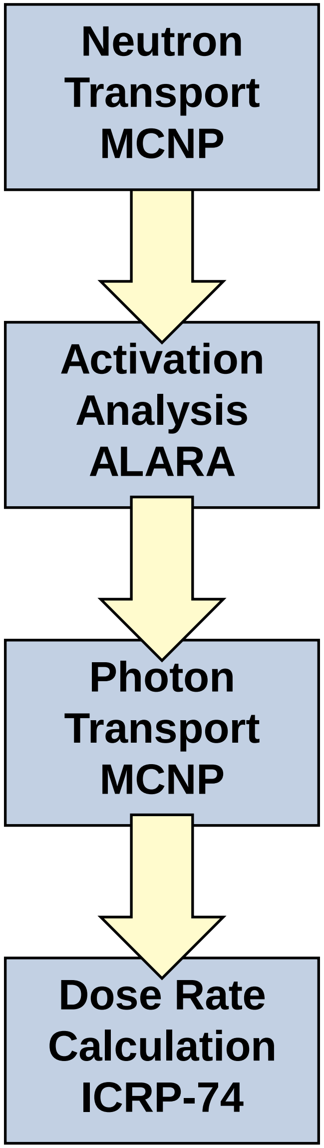


MRS



Methodology used by AAMI to estimate dose rates

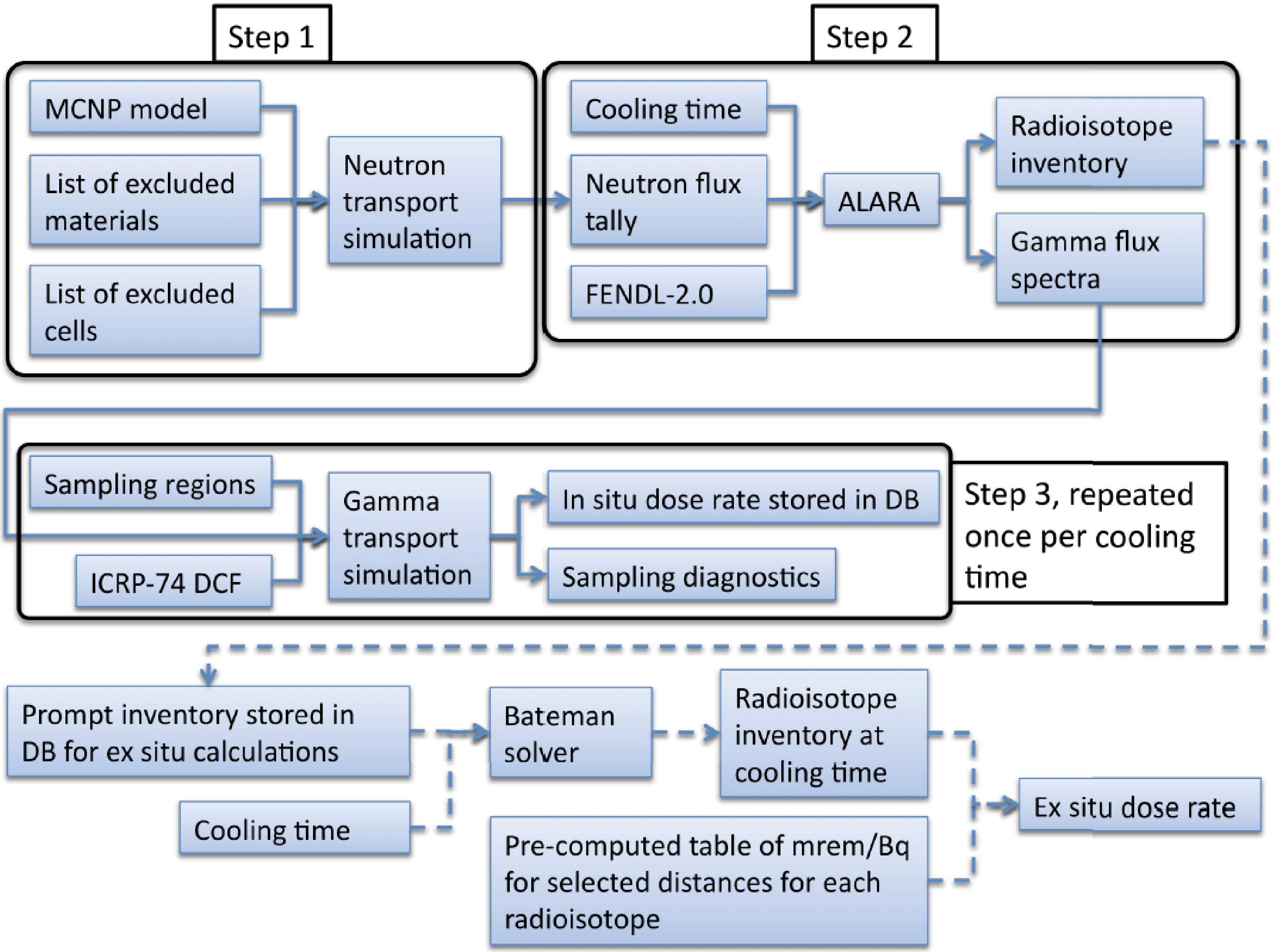
- **AAMI automates the dose rate calculations by conducting the following three steps:**
  - **— *Step 1*: Neutron transport calculation using the MCNP 3D model and FENDL-2.1 data library to obtain 175-group flux spectra in each component of interest**
  - **— *Step 2*: Activation analysis of components using the activation code, ALARA, to compute the γ-ray intensities and spectra for each cell and for several different cooling times after a shot**
  - **— *Step 3*: γ-rays computed in the second step are sampled and emitted from each activated component, and propagated by a transport simulation through the entire MCNP model of the Target Bay**



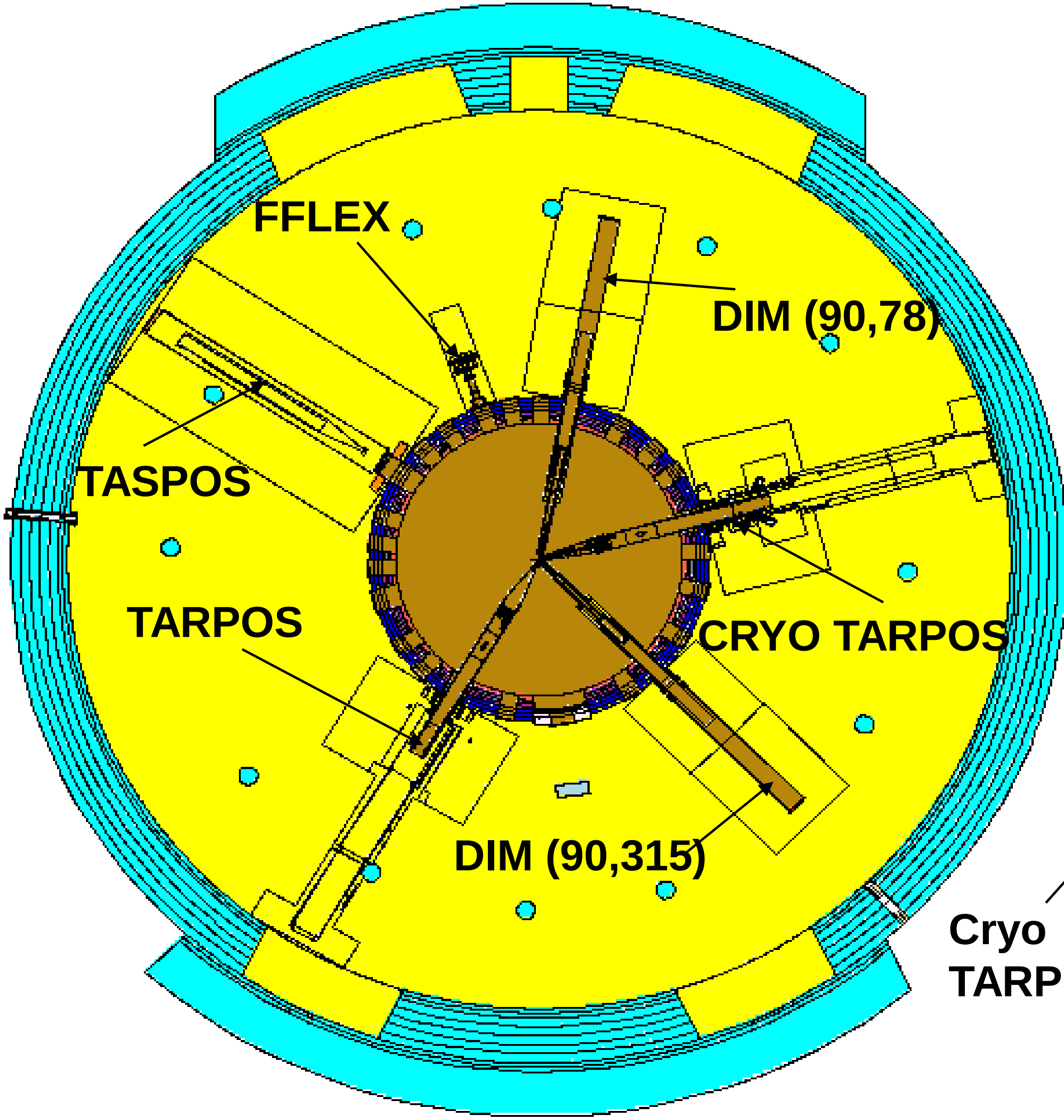
Methodology used by AAMI to estimate dose rates (Cont.)

- **Gamma transport performed with user provided source subroutine for MCNP**
- **Volume-based sampling used with weight adjustment to correct bias for source strength**
- **γ-ray fluxes are tallied using a fine 3-D grid over the entire Target Bay, and are converted into dose rates using the ICRP-74 anterior-posterior effective fluence to dose conversion coefficients**
- **3-D dose rate maps for different cooling times are stored in a database**

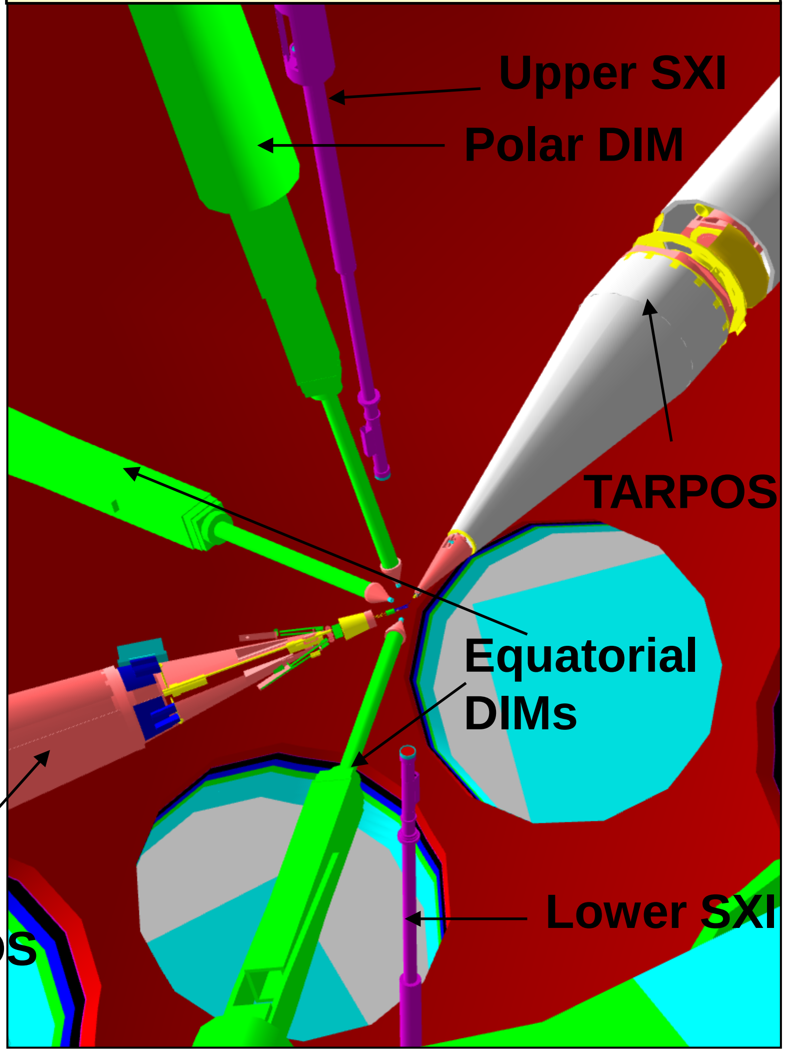
AAMI flow chart



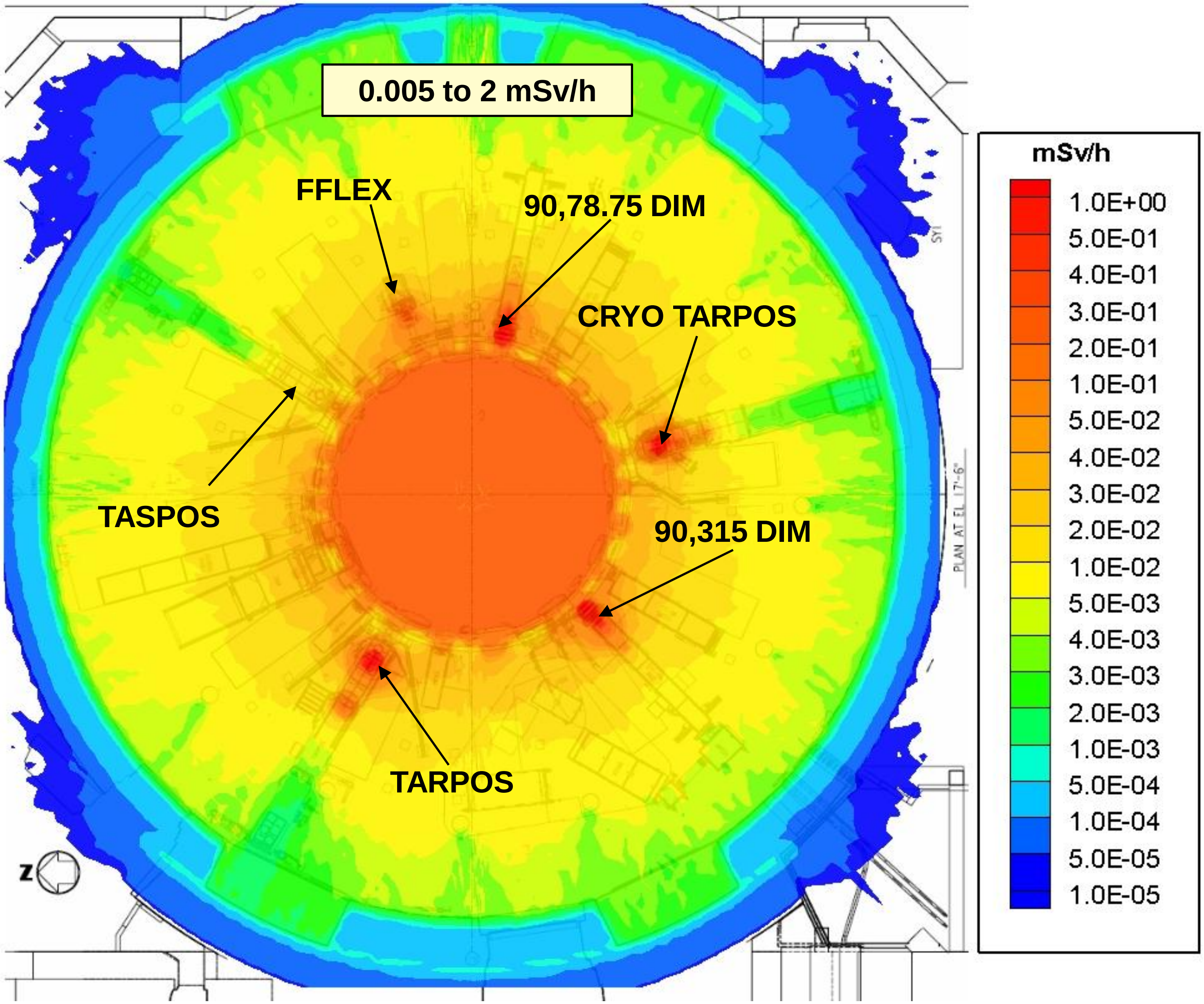
MCNP model of the Target Chamber during a shot



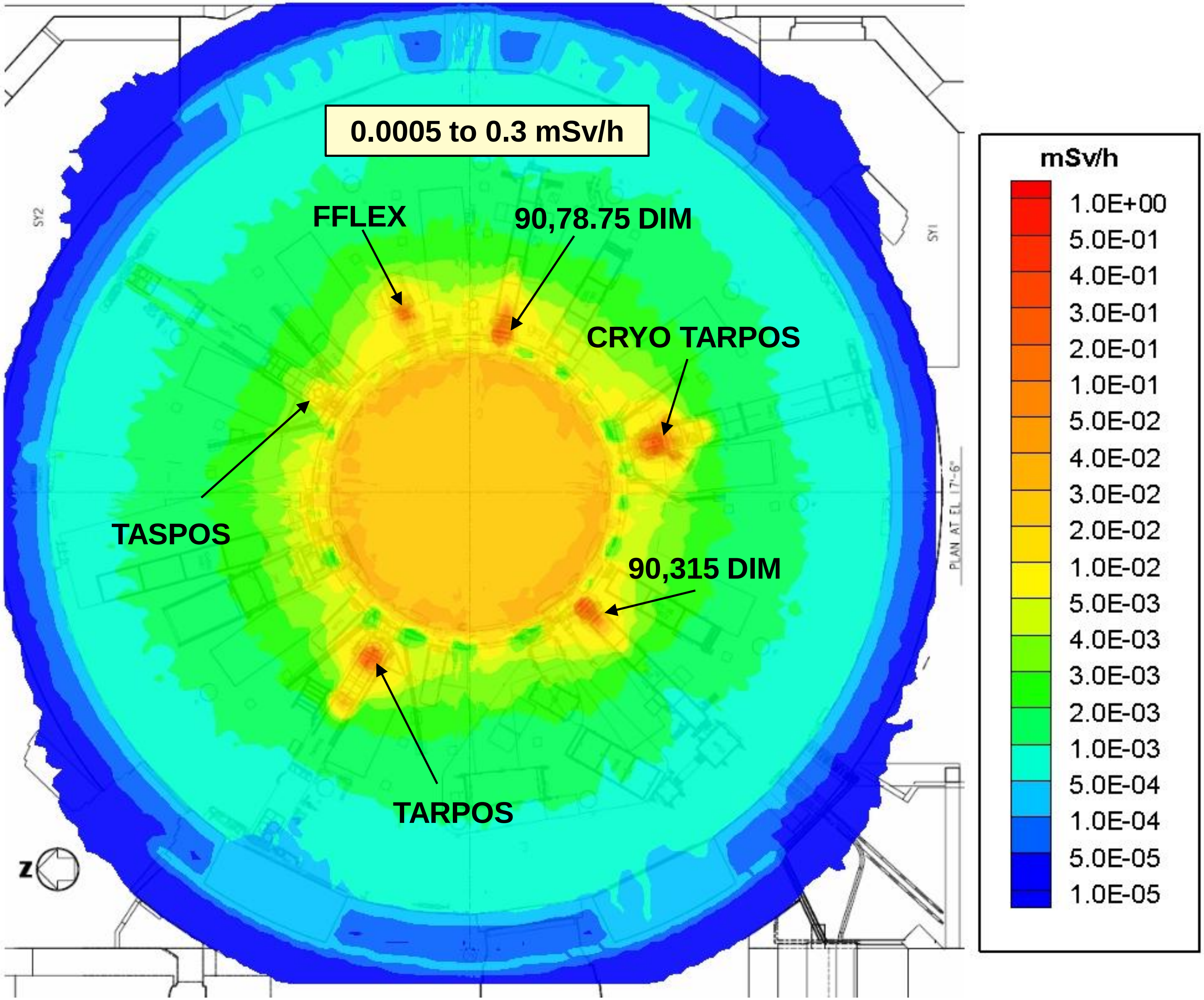
3D Model of the inside of the TC



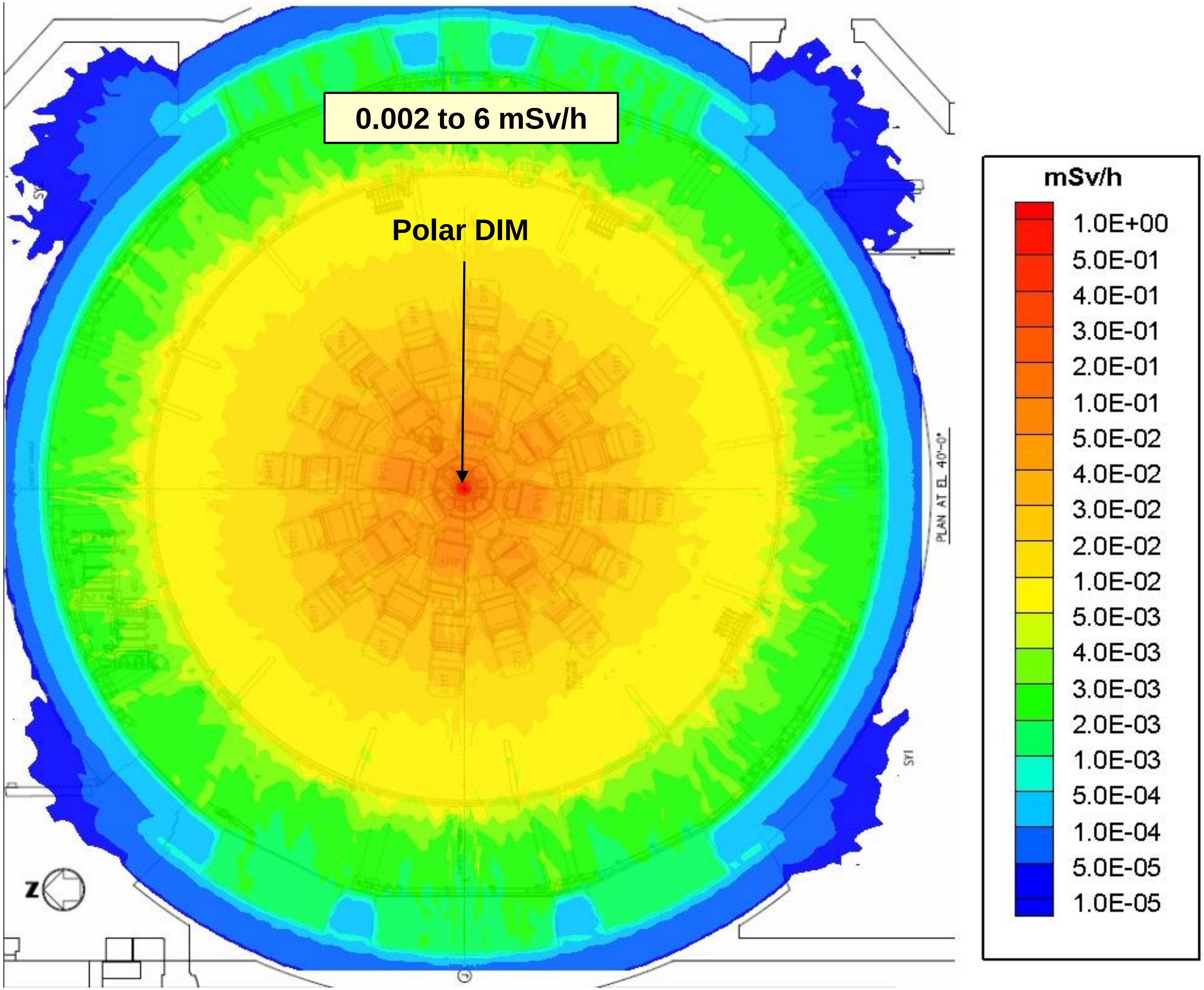
Dose rate map at Target Chamber equatorial plane following a 20MJ/7.1x10^{18} shot (5 days cooling)



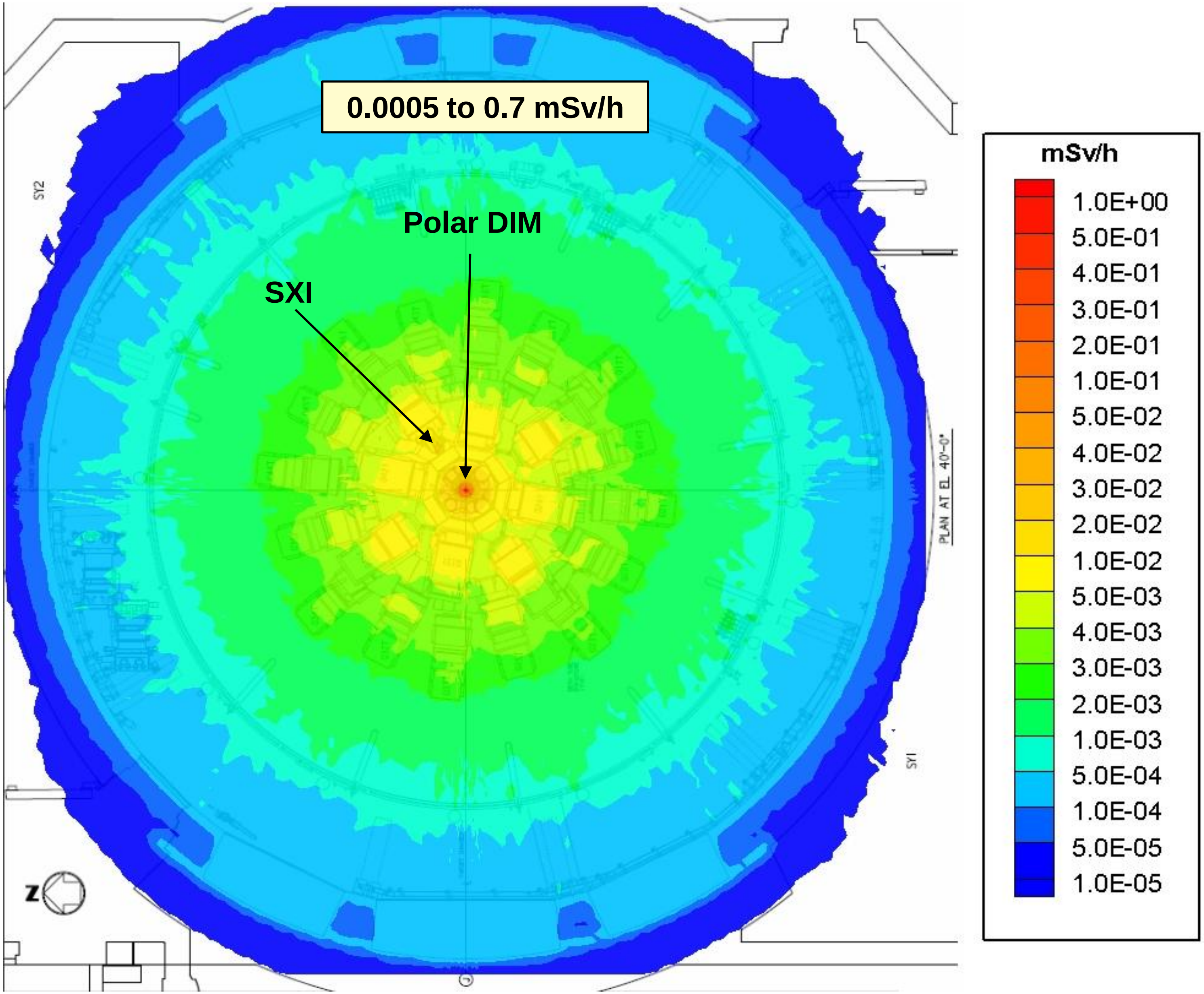
Dose rate map at Target Chamber equatorial plane following a 20MJ/7.1x10^{18} shot (7 days cooling)



Dose rate map on platform above Target Chamber following a 20MJ/7.1x10^{18} shot (5 days cooling)



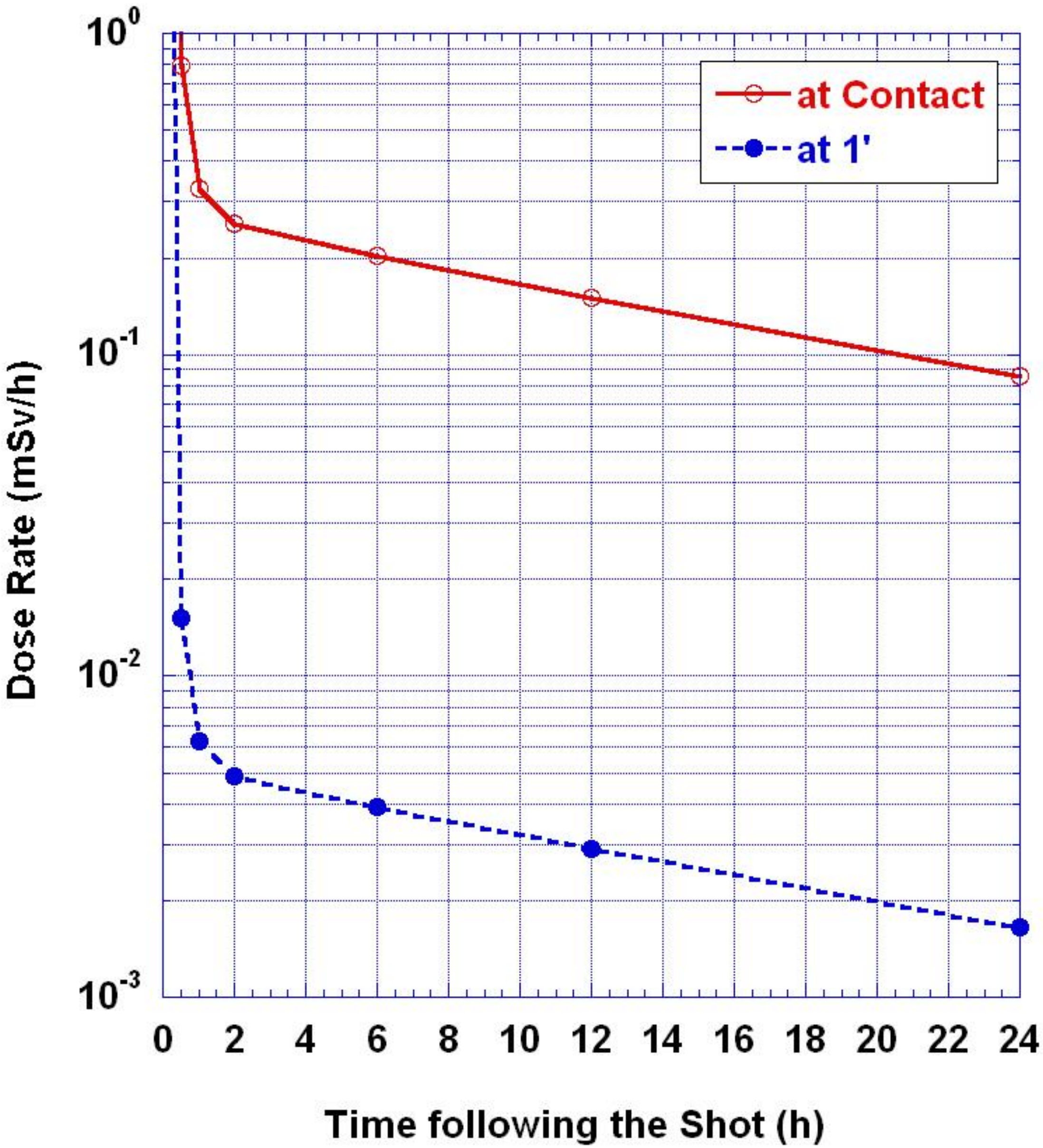
Dose rate map on platform above Target Chamber following a 20MJ/7.1x10^{18} shot (7 days cooling)



Dominant contributors to dose inside the Target Bay

- **Large number of aluminum and stainless steel components are activated and the principal contributors are:**
- **Short term**
  - ✓ ^{28}Al ($T_{1/2}$ = 2.2 m; <γ> = 1.78 MeV)
  - ✓ ^{27}Mg ($T_{1/2}$ = 9.5 m; <γ> = 0.9 MeV)
- **Intermediate term**
  - ✓ ^{56}Mn ($T_{1/2}$ = 2.6 h; <γ> = 1.7 MeV)
  - ✓ ^{24}Na ($T_{1/2}$ = 14.7 h; <γ> = 4.1 MeV)
- **Long term**
  - ✓ ^{58}Co ($T_{1/2}$ = 70.9 d; <γ> = 0.8 MeV)
  - ✓ ^{54}Mn ($T_{1/2}$ = 312.2 d; <γ> = 0.8 MeV)

Dose rates near polar DIM after 10^{15} shot

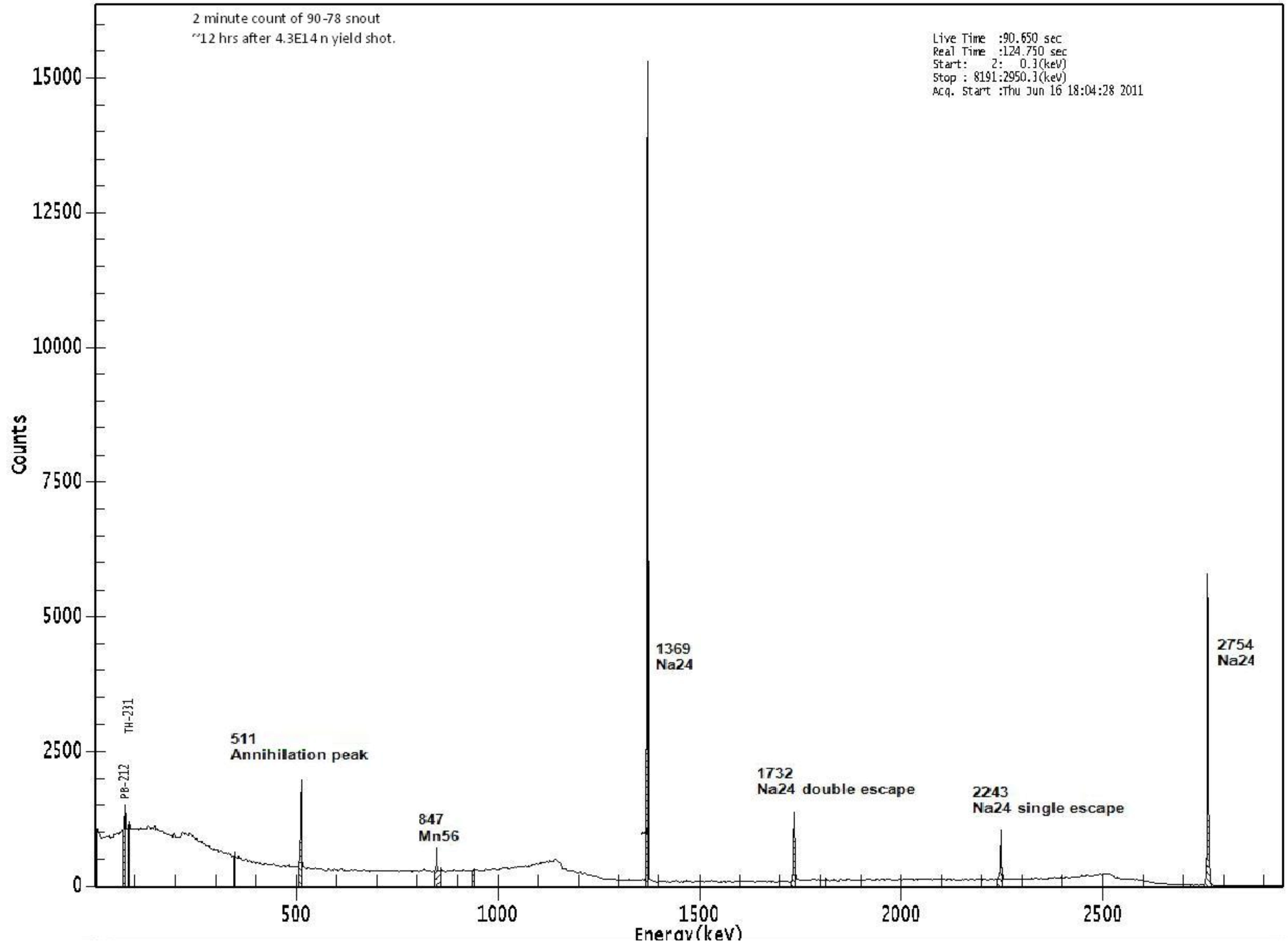


Dose rate at 1' from tip of the snout:

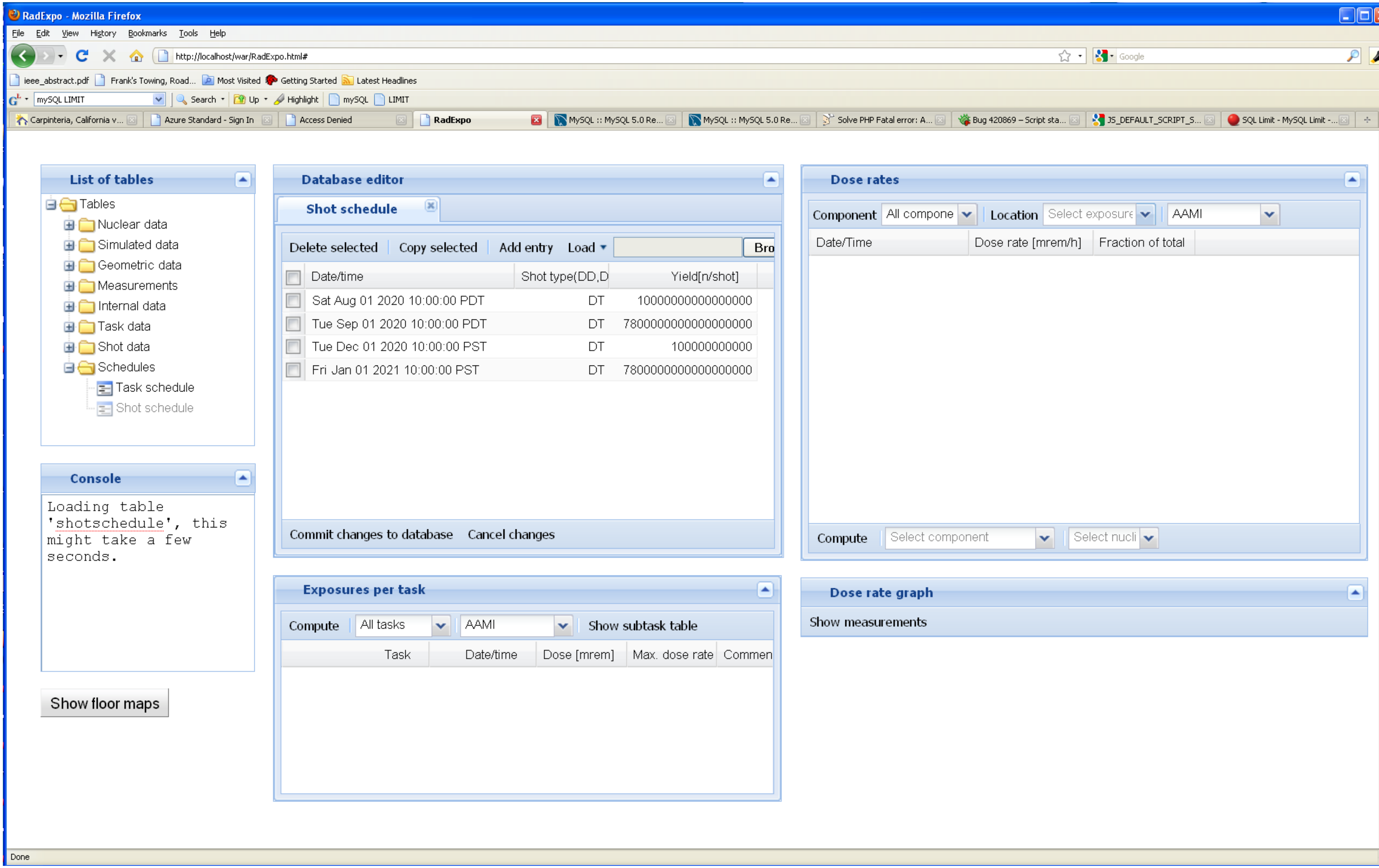
- **4 μSv/h after 6 h**
- **3 μSv/h after 12 h**
- **1.7 μSv/h after 1 day**

Gamma spectrometry

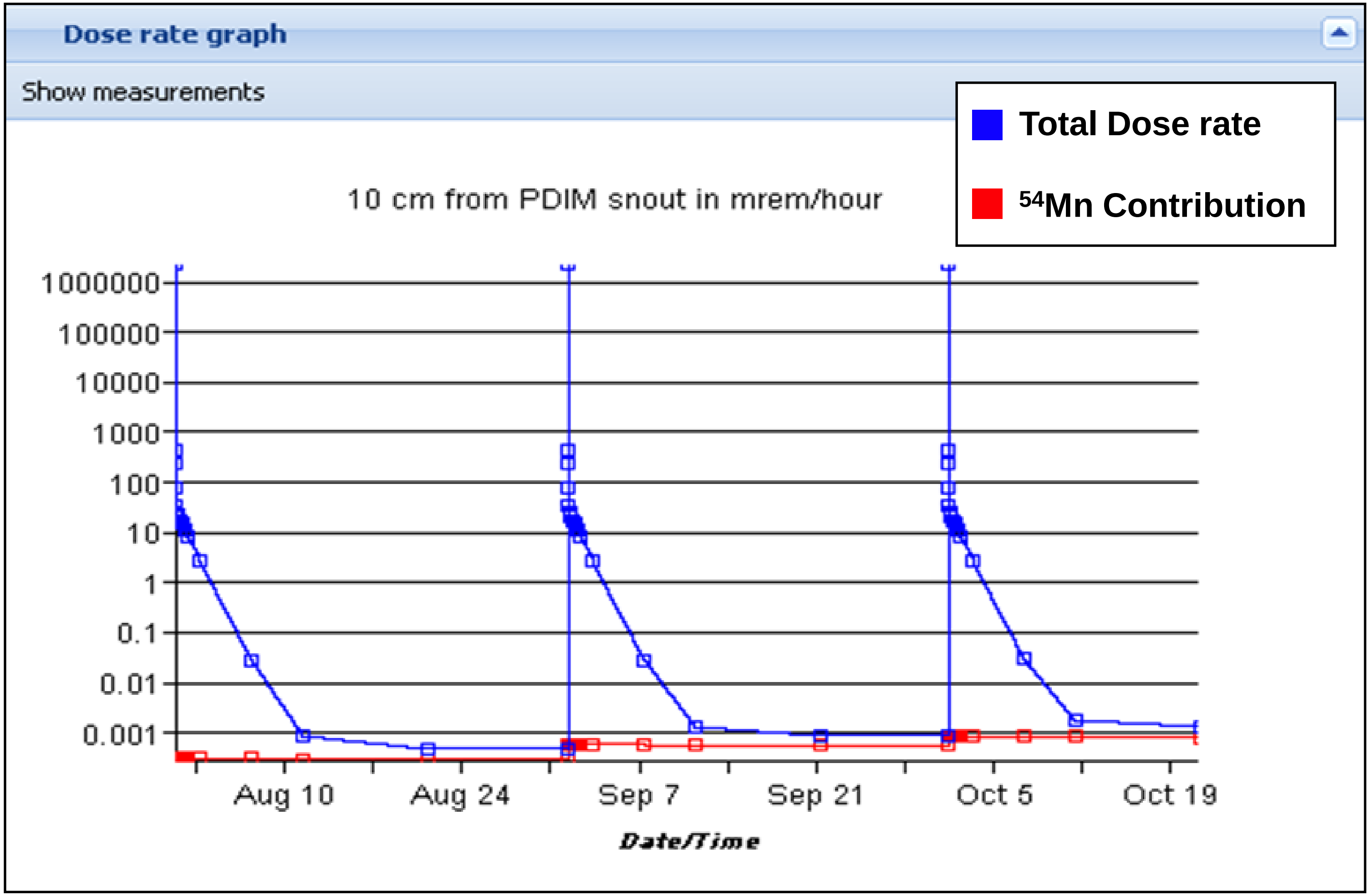
- **Spectrum obtained on a DIM snout 12 hours following 4.3x10^{14} shot**
- **Measured snout dose rates are typically between 0.03 and 0.15 mSv/h on contact when they are removed 4 hours after a 5x10^{14} shot**
- **Gamma spec readings of Target Bay and Target Chamber diagnostic components show primarily ^{24}Na and ^{56}Mn activities**



NEET is a web-based application

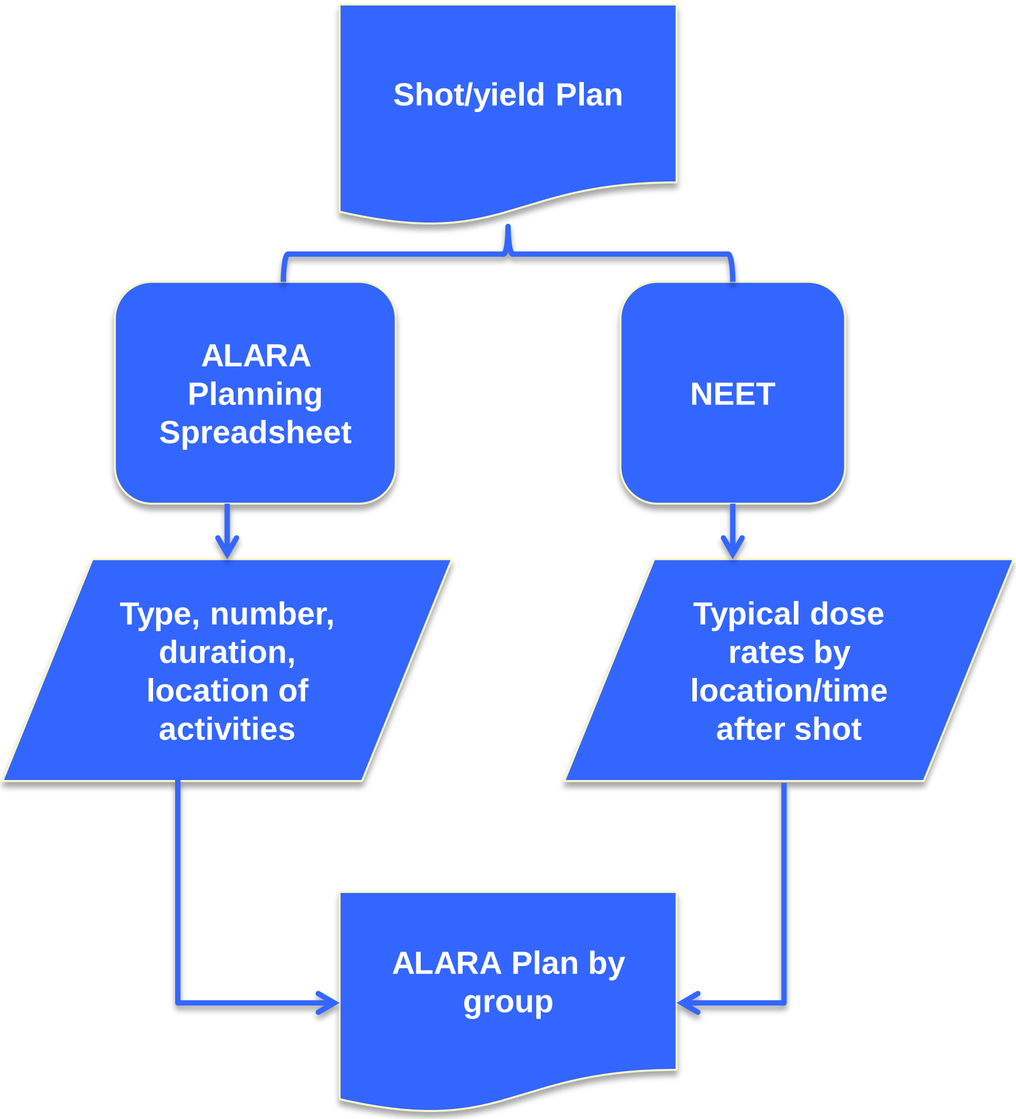


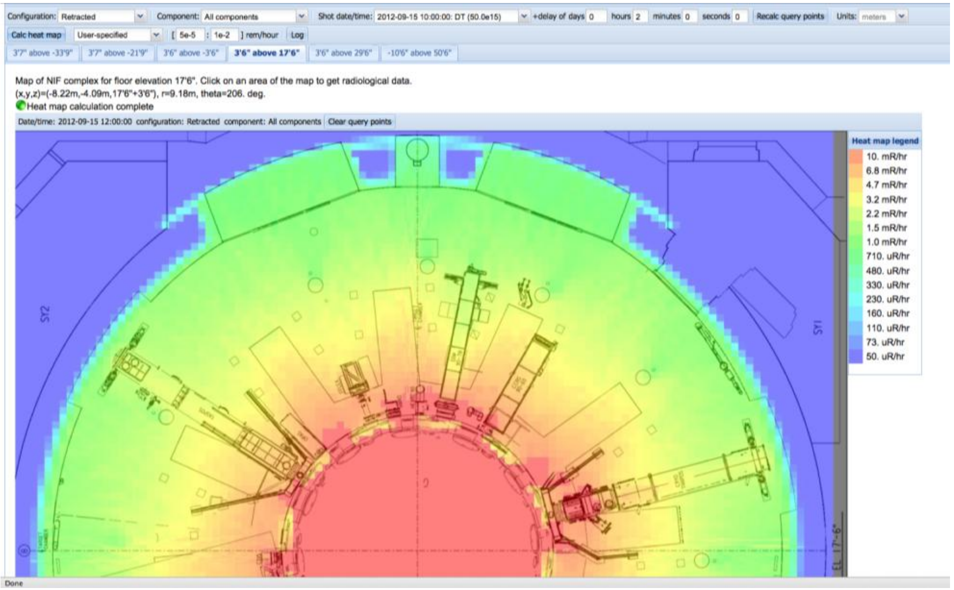
Dose rates following a set of 10^{16} shots

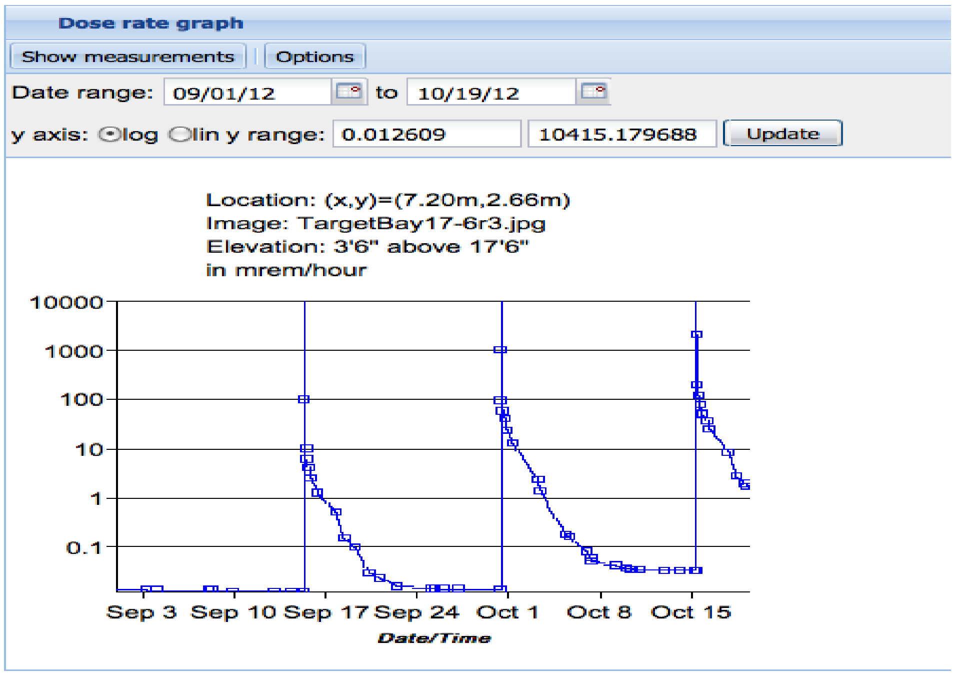


Radiation environment is dominated by short-lived isotopes

NEET is used to develop annual ALARA Plan







Summary

- **A detailed model of the TB has been developed to characterize the radiation environment within the TB following different categories of shots**
- **A set of computational tools was developed to help in estimating potential radiation exposure to workers from activated materials inside the Target Bay**
- **The Automated ALARA-MCNP Interface (AAMI) provides an efficient, automated mechanism to perform the series of calculations required to create dose rate maps for the entire facility**
- **The NIF Exposure Estimation Tool (NEET) is a web-based application that combines the information computed by AAMI with a given shot schedule to compute and display dose rate maps as a function of time**
- **Components close to TCC during a shot, like parts of the CryoTARPOS, TARPOS and the 3 DIMs represent a major source of gamma decay after being retracted outside the TC**

Summary (cont.)

- Seven days following a 20 MJ shot, the dose rates in the immediate vicinity of the retracted components drop to < 0.2 mSv/h and the general ambient dose rate near the TC drops to < 0.01 mSv/h
- Primary NIF components, including the Target Chamber, Diagnostics and Beam Line Components, are constructed of aluminum
- Near-term Target Bay accessibility is driven by the decay of the aluminum activation product ^{24}Na
- NEET results are used to develop annual ALARA Plan
- Worker doses are tracked and managed using Sentinel software


NIF